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BIOLOGICAL FACTORS IN THE CONTROL OF THE MOUNTAIN PINE BEETLE

by
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February 8, 1939

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February 10, 1939

Washington, D. C.

Dear Dr. Craighead:

There are enclosed two copies of a laboratory report by Mr. Bedard entitled "Biological Factors in the Control of the Mountain Pine Beetle". The extra copy is forwarded for whatever disposition you may desire to make; however, a copy of the report has been forwarded to Mr. Brown at the New Haven Laboratory.

This manuscript, which should be considered as a progress report bringing up to date data obtained from our infestation study, advances some interesting and valuable information. Although as yet we are not ready to advance any positive recommendations in connection with the administration of artificial control for the reduction of mountain pine beetle epidemics in white pine, there are several points which offer some possibilities. Small thin-barked infested trees or those isolated infested trees which are to be found along the high, open ridges, and which are the most expensive to treat, can perhaps be eliminated from all future projects.

We should appreciate having you comments in connection with this report.

Respectfully yours,

Enclosures

JAMES C. EVENDEN
Senior Entomologist

cc to:
Mr. Miller
Mr. Keen
Dr. Beal
Mr. Brown

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Coeur d'Alene, Idaho
February 6, 1939

BIOLOGICAL FACTORS IN THE CONTROL OF THE MOUNTAIN PINE BEETLE

Although the subject of biological control has been thoroughly discussed by a number of authors, there still continues to be considerable controversy in any discussion of the subject. The effect of biological agencies appears to be decidedly beneficial under one set of circumstances and inocuous or even detrimental under others. It is the object of this study, therefore, to evaluate the various natural agencies effective in the control of the mountain pine beetle and to develop some modification of present control practices whereby the benefits of natural control would not be nullified by mechanical methods.

To this end data have been gathered during the past three seasons from an infestation of the mountain pine beetle in western white pine on the Coeur d'Alene National Forest. The study was actually begun several years ago, but it was only during the past three seasons that a crew of CCC enrollees was available to secure quantitative data in conjunction with a detailed study of the mountain pine beetle infestation.

During the earlier portion of the first season's study, each tree was felled and examined at 10-foot intervals along the bole, starting at five feet. Later, however, the interval was extended to 20 feet when it was found that this could be done without altering the character of the data, so that examinations were made therefore at 5, 20, 40, 60 feet, etc., up to the height of infestation. The 5-foot sample was considered

representative of the basal 10 feet of the bole, the 20-foot sample the next 20 feet, the 40-foot sample from 30 to 50 feet, etc. The last sample was taken at a point midway between the top of the last 20-foot log and the height of infestation. At each point of examination one-half square foot of bark was removed on the north, east, south and west sides of the tree and complete insect population data were recorded for each half-square-foot sample.

In totaling these data sheets, the total population for each log was first determined. Then the totals for each individual factor in each log were added together and their sum divided by the total bark surface of the tree in order to secure the tree average for each factor. In this way the unequal bark surface represented by the various samples was weighted and the total for the tree was more accurate.

IMPORTANCE OF BIOLOGICAL AGENTS IN CONTROL

Relative to infestations of the mountain pine beetle in western white pine, there is no doubt that for the most part the action of the biological agents is beneficial. In the development of the mountain pine beetle from egg to emergence there is an average mortality of approximately 90 percent which is caused to a large extent by various biological agencies. Table I has been prepared to show the progressive mortality which occurs throughout the various developmental stages.

TABLE I

Mortality to Mountain Pine Beetle During Development

Developmental stage	Trees examined	Bark surface	Av. per sq.ft.	Decrease to succeeding stage		Percent of total decrease
	no.	sq.ft.	no.	no.	percent	
Egg	46	10,030	169.9	63.7	37.5	37.5
Small larva	58	10,033	106.2	43.5	41.0	25.6
Large larva	46	9,039	62.7	23.3	37.2	13.7
Pupa	30	5,939	39.4	13.9	35.3	8.2
New adult	38	9,475	25.5	11.4	44.7	6.7
Emergence	36	8,282	14.1			
Total	254	52,798	169.9	155.8		91.7

It is quite apparent in table I that mortality factors are decidedly important in holding down infestations of the mountain pine beetle. Chief among the various causes of mortality are the biological agents such as mites, which are active in destroying eggs; parasites, which are effective in reducing the number of larvae; and predators, which attack larvae, pupae and new adults.

GENERAL COMPARISON OF ABUNDANCE

Three seasons' data are available to compare the status of beneficial biological factors. In table II the beneficial agencies have been divided to show woodpecker work, insect parasites, insect predators, work by secondary bark beetles and wood-boring beetles. The last two have been grouped under the heading "robber work". These data are compared with mountain pine beetle broods for the 1935, 1936, and 1937 seasons. The year of attack has been used to designate the infestation,

although examination of the trees was made in the year of emergence, which would be one year after attack.

TABLE II

Abundance of Beneficial Biological Agents During 1935-36-37

Year	Trees examined	Bark surface	Average per square foot: D.m. brood	Parasites	Predators	Robber work	Woodpecker work
			no.	no.	no.	sq.in.	sq.in.
1935	133	25,327	7.7	4.7	2.4	7.7	6.6
1936	106	20,258	38.3	3.6	1.4	18.0	5.2
1937	56	15,159	24.0	1.7	0.8	15.1	11.8

Table II shows that there have been decided decreases in abundance of both parasites and predators in the 1936 and 1937 trees. Mountain pine beetle broods were exceptionally scarce in 1935, abundant in 1936 and approximately midway between the two in 1937, although the greater amount of woodpecker work may account for the decrease in 1937.

Robber work was exceptionally abundant in the 1936 and 1937 trees, probably owing to the fact that attacks by the mountain pine beetle were less numerous per square foot during these two seasons, thus allowing room for the secondary insects to concentrate in the lower bole rather than in the top above the height of mountain pine beetle infestation.

The continued decrease in parasites and predators in 1937 is difficult to explain. In last year's report, it was thought that if the mortality to these insects occurred prior to their emergence, it

might have been caused by starvation or cannibalism owing to the scarcity of broods in the 1935 trees. If, however, it had occurred after emergence, it might have resulted from lack of suitable places for oviposition owing to the decrease in number of trees infested in 1936. These explanations do not hold, however, for the decrease in 1937, because there were abundant broods as well as more abundant infestation.

Some beneficials showed greater losses than others as shown in table III.

TABLE III
Change in Status of Beneficials

	Average per square foot		
	1935	1936	1937
	no.	no.	no.
Coeloides	4.6	3.1	1.4
Chalcids	0.2	0.5	0.3
Medetera	0.9	0.8	0.5
Lonchaea	1.1	0.1	0.01
Clerids	0.3	0.4	0.1
Ostomids	0.1	0.1	0.1
Phaonia	0.01	0.003	0.0

In table III it is shown that the two chalcids Cecidostiba and Pachyceras increased in 1936 so that the braconid Coeloides alone showed a decrease among the parasites. Among the predators in 1936, Medetera decreased but slightly, clerids increased, and ostomids

remained unchanged, so that _Phaonia_ and _Lonchaea_ suffered most of the loss apparent among the predators. Since _Phaonia_ is of such low abundance as to be of little influence, practically all of the loss resulted from a decrease in _Lonchaea._ It is interesting to note in this case that decreases occurred only in those insects which pupate within a definate pupal case.

In the 1937 trees, all beneficial insects excepting ostomids showed decreases. Here again, however, greatest losses occurred in those insects pupating within definite pupal cases. It is thought that control work may have had some influence on beneficial insect population, as the two areas sampled in this study have had bark beetle control during the course of the investigation.

EFFECT OF VARIOUS FACTORS ON ABUNDANCE

There are certain limiting factors which affect the population of beneficial agencies. These factors are discussed in the following section under the headings: availability of host, site moisture, accessibility of host, tree diameter, exposure, and location.

Availability of Host

As would be expected, it is essential that host material suitable for oviposition must be available at the time when adult parasites and predators are emerging. Table IV shows the abundance of beneficial agents in trees attacked at various times during the

season. Early attacked trees are those attacked by the mountain pine beetle during June; midseason attacks occur during July and the first part of August; while late attacks are made from late August to the end of the season.

TABLE IV
Population of Beneficials in Various Attack Periods

Year	Attack period	Average per square foot: Parasites	Predators	Secondary work	Wood borer work	Woodpecker work
1935	Early	7.0	3.8	4.9	5.8	8.7
	Midseason	3.7	1.8	4.5	2.2	6.1
	Late	3.7	1.2	6.6	0.3	0.1
1936	Early	3.3	1.0	10.2	5.2	8.1
	Midseason	4.7	1.5	9.7	2.6	4.7
	Late	1.6	1.7	32.8	1.9	1.3
1937	Early	2.4	0.5	9.5	9.1	22.6
	Midseason	1.2	1.0	9.3	4.2	9.2
	Late	4.0	0.1	18.5	1.0	4.3
Average	Early	4.7	2.1	7.7	6.2	11.0
	Midseason	3.2	1.5	7.3	2.9	6.6
	Late	2.5	1.3	24.5	1.4	1.6

According to the data shown in table IV parasites are generally most abundant in the early attacks, next in abundance in the midseason attacks, and least in the late attacks. This also holds true for predators. The reason for this is that during August, when most of the parasites oviposit, the early attacks contain mostly mature larvae, thus providing the greatest quantity of suitable host material for the parasites. At this time only a few of the earlier midseason attacks

have attained sufficient development to provide suitable hosts, while a few of the previous season's late attacks also contain suitable larvae. Predators are prevalent in the earlier attacks because these are the only broods available when most of the predators oviposit during midseason.

There is some variation from the normal condition to be noted in table IV, probably resulting from the heavy mortality among beneficials during the last two seasons. It is also possible that there has been a loss of synchronization between parasites and host because it is known that the last three seasons witnessed some changes in mountain pine beetle seasonal history.

Work by secondary bark beetles is most prevalent in late attacks because maximum secondary population is attained at the end of the season. Wood-boring beetles appear during July, when the early attacks are the most suitable trees for oviposition; hence the preponderance of this work in the early attacks. Woodpeckers feed on mountain-pine-beetle-infested trees during the winter months and select the early and midseason attacks because of the more mature broods. Thus it is seen that availability of suitable host material limits the action of beneficial agencies.

Site Moisture

A second factor which may properly be considered a corallary of "availability of host" is "abundance of host". In general, parasites

and predators seek out trees containing an abundant supply of host material, although there are many heavily brooded trees which do not contain a great number of beneficial insects. This may be only an apparent preference resulting from the fact that a more numerous host may permit a greater amount of oviposition. In table V, parasites and predators are compared with the abundance of mountain pine beetle brood.

TABLE V
Parasites and Predators According to Host Abundance

D. m. brood per square foot	1-10	11-20	21-30	31-40	41-50	51+
Parasites	1.5	2.9	5.7	2.7	2.9	2.7
Predators	0.5	0.8	1.3	0.6	1.4	2.6

Table V shows that parasites are not influenced as much by brood abundance as are predators. In any event the difference is not sufficient to effect the correlation which is shown in table VI, in which the various beneficial agencies are shown according to the moisture of the site on which the infested tree is growing.

It is apparent in table VI that parasites and predators are most plentiful on wet sites and least abundant on dry sites, while the opposite is true of robber work.

TABLE VI
Status of Beneficial Agents According to Site Moisture

Site moisture	Trees examined	Bark surface	Average per square foot			
			Brood	Parasites	Predators	Robber work
	no.	sq.ft.	no.	no.	no.	sq.in.
Wet	67	15,292	35.7	6.0	2.8	17.7
Medium	86	19,434	20.6	3.3	1.6	17.9
Dry	143	25,892	14.9	2.4	1.0	24.3

Accessibility of Host

One of the most important factors governing the effectiveness of parasites and predators in mountain-pine-beetle-infested material is the ease with which the host material can be reached. The parasite Coeloides dendroctoni Cush., which oviposits through the bark, is not able to parasitize larvae which are beneath bark thicker than the length of the ovipositor. On the other hand, the two chalcid parasites Pachyceras eccoptogastari Ratz. and Cecidostiba dendroctoni Ash. enter the bark by means of parent-adult emergence holes and thus are found most plentiful where these holes are most numerous. In table VII the distribution of various factors is shown according to bark thickness.

TABLE VII
Effect of Bark Thickness on Beneficials

Bark thickness	0.1	0.2	0.3	0.4-0.5	0.6-0.7	0.8+
No. samples	107	233	159	247	67	24
Bark surface	5,805	13,860	9,328	11,541	3,040	1,610
Coeloides	5.2	4.9	2.9	2.9	4.5	1.6
Chalcids	0.1	0.4	0.6	0.5	0.4	1.0
Total parasites	5.3	5.3	3.6	3.4	4.9	2.6
Medetera	0.2	0.6	0.9	0.6	2.2	2.5
Lonchaea	0.02	0.2	0.05	0.3	3.1	3.2
Clerids	0.2	0.4	0.2	0.5	0.6	0.8
Ostomids	0.06	0.1	0.1	0.1	0.3	0.2
Phaonia	0.01	0.0	0.0	0.01	0.0	0.0
Total predators	0.5	1.3	1.3	1.6	6.1	6.6
_D. m._ attacks	2.9	3.5	3.9	4.5	8.7	7.7
Parent emergence holes	2.8	3.0	2.4	4.1	8.1	8.5

In this table it can be seen that _Coeloides_ population is greatest in the thinner bark, while the two chalcid parasites are most plentiful in thicker bark where parent-adult emergence holes are numerous. Similar to the chalcids, all predators tend to be most numerous in the thicker bark for the same reason. This not only means that _Coeloides_ is most numerous in smaller, thinner-barked

trees while other beneficials are most common in larger, thicker-barked trees, but that *Coeloides* also prefer the upper bole, while chalcids and predators prefer the lower bole.

Tree Diameter

The effect of tree diameter on beneficial insects undoubtedly depends to a large extent upon the influence of accessibility and availability of the host. In table VII the various beneficial agencies are shown according to the diameter of the tree.

TABLE VIII
Effect of Tree Diameter on Beneficials

D.b.h. in inches	6-10	11-12	13-18	19-24	25+
No. trees	30	43	119	74	29
Bark surface	1,926	4,910	21,351	21,096	11,451
D. m. attacks	5.3	5.2	5.2	6.1	5.1
D. m. brood	4.3	17.5	19.9	22.8	26.1
Parasites	4.4	8.6	4.3	2.8	0.8
Predators	0.5	1.0	1.3	1.9	2.3
Robber work	27.2	25.7	33.7	40.8	39.2

The average of all trees examined at the time of emergence during 1936, 1937, and 1938, shows some interesting facts. It is apparent in table VIII that trees under 10 inches in diameter are nonproductive of mountain pine beetle brood and that they contain a sufficient number of parasites and predators to make their treatment

more harmful than beneficial. Maximum parasite population is found in the 11- and 12-inch diameter class because these are the thinnest barked trees which contain sufficient D. m. brood.

Exposure

No data are shown for exposure of the site on which the tree is growing, nor for exposure of the tree bole. Exposure of the site has been eliminated because site moisture and site are of such importance as to mask any influence which exposure itself might have. Exposure of the bole has been eliminated because when this correlation was made there was not sufficient variation in abundance of beneficial agents on the four sides of the tree to indicate any influence.

Location

Throughout the course of the infestation study the data have been kept separate for all of the various units on the Coeur d'Alene National Forest. The first year, trees were examined on seven units, but during the two subsequent years, the work was concentrated on three units in order to secure a better sample and thus have a better basis for comparing the various areas. In table IX the abundance of beneficial agents is shown for the Honeysuckle, Yellow Dog River, and Yellow Dog River Face units for the 1935, 1936 and 1937 trees.

TABLE IX
Abundance of Beneficials in the Various Units

Unit	Year	Trees examined	Bark surface	Average per square foot: Parasites	Average per square foot: Predators	Average per square foot: Robber work
		no.	sq.ft.	no.	no.	sq.in.
Honeysuckle	1935	55	13,004	2.6	2.7	13.6
	1936	31	8,000	1.5	1.1	28.5
	1937	52	14,255	1.7	0.8	28.3
Yellow Dog River	1935	12	2,340	4.6	2.4	14.5
	1936	25	3,081	9.9	0.9	21.5
	1937	2	248	5.8	1.8	2.0
Yellow Dog River Face	1935	13	2,569	6.5	1.6	18.8
	1936	32	5,913	3.8	1.2	18.1
	1937	2	656	0.2	0.3	5.3

It is apparent in table IX that there is a decided difference in population of beneficials in the different areas and that there has been a considerable change within the units themselves. The population of parasites was noticeably higher in the Yellow Dog areas in 1935 than in the Honeysuckle unit, while the latter contained the highest predator population. Conditions within these areas have changed to such an extent, however, that the Yellow Dog River unit is the only one which apparently contains a parasite and predator population worth considering. Unfortunately the control work in the fall of 1937 in the two Yellow Dog areas left only four 1937 trees for examination in 1938, so that these records are not based on very many samples.

Because of the control work in Yellow Dog, and logging in Honeysuckle, it is difficult to place the cause of the change in status among the beneficials. The effect of the control work, if any, will not be felt until the 1938 trees are examined. Logging in the Honeysuckle unit undoubtedly has had some effect upon the beneficials. The decrease in predators is attributed to the fact that the larger infested trees along the creek bottom handy to the road are being picked up annually by loggers. Since these trees have the greatest population of predators, it is believed that the removal of these trees has caused a decrease among the predators. Road and logging slash in this area have undoubtedly contributed to the increase in secondary bark beetle and wood borer work in this area.

From the preceding discussion concerning the effect of various factors on the abundance of beneficial agencies, it is apparent that there is a considerable variation within different infested areas. Within an individual area two factors, namely, accessibility and availability of the host, are most important in determining the abundance of beneficials. These two major factors are in turn influenced by site and tree diameter. Thus, of the areas examined, parasites for example are most abundant in the Yellow Dog River unit. Within this unit, they are concentrated in the thin-barked portions of the smaller, early-attacked trees which are growing on wet sites. Predators on the other hand are most abundant in the same unit, but are found mainly in the thick-barked portions of the larger, early-attacked trees which are growing on wet sites.

Mortality of Beneficials

Very little work has been done to determine the mortality which occurs to beneficials throughout their development. Table X shows a comparison of the conditions in the 1937 trees which were examined in the fall of the season of attack, and conditions which prevailed in those 1937 trees examined in 1938 just prior to emergence.

TABLE X
Comparison of Conditions in 1937 Trees Prior to and Following Winter

Time of examination	Fall 1937	Spring 1938
No. trees examined	131	56
Bark surface	21,273	15,159
Coeloids	2.4	1.4
Chalcids	0.03	0.3
Total parasites	2.5	1.7
Medetera	0.7	0.5
Lonchaea	0.01	0.01
Clerids	0.4	0.1
Ostomids	0.08	0.1
Phaenia	0.0	0.0
Total predators	1.2	0.8
Robber work	22.4	26.9

Table X shows that there was a 32 percent decrease in parasites, a 33 percent decrease in predators and a 20 percent increase in robber

work over the winter. However, these data only serve to show that there is some loss of beneficials during development. Owing to the fact that different trees are represented in the fall and spring examinations, too much dependance can not be placed in table X.

PRACTICAL APPLICATION OF THE STUDY

Although only three seasons have been devoted to a detailed study of the beneficial agents associated with mountain pine beetle infestations in western white pine, it is already apparent that additional study will yield valuable information of a practical nature. For example, in the 1933 control work on the Coeur d'Alene National Forest one area was selected in which all so-called "parasite trees" were left untreated in an attempt to foster an increase of parasites and predators while at the same time the beetle population was decreased. This work entailed the examination of every infested tree in order to ascertain the abundance of beneficial insects, and in many cases there was considerable doubt as to the tree's status. With present knowledge, however, the work would be simplified by restricting it to trees containing an advanced brood stage, growing on moist creek bottom sites. In addition, specifications as to tree diameter and bark thickness would further facilitate the work.

The value of beneficial agents in control is another important point which will be learned from this study. Already there are indications that beneficials play a part in fluctuations of mountain

pine beetle infestations. The exact importance of their role has not been learned, but when this point is established it will aid in the prognostication of anticipated increases and decreases in mountain pine beetle infestations in western white pine.

In considering the possibility of fostering native parasites and predators it is essential to know which are the most effective of all the beneficial insects. It is practically impossible to save all of them because the different species attain maximum abundance under divers circumstances, and it is therefore logical to direct the work so as to assist those species which are most important. It is planned that this study will provide such information in order to preserve the most valuable species, and also to serve as a better basis for determining the status of an infestation.

SUMMARY

The object of this study is to evaluate the biological agencies effective in the control of the mountain pine beetle in western white pine for two purposes, (1) to attempt some modification of mechanical control whereby the benefits derived from natural control factors would not be nullified, and (2) to provide a better basis for prognosticating anticipated increases or decreases in mountain pine beetle infestations.

Results of this study support the belief that biological agents

play an important role in reducing broods of the mountain pine beetle. During the 1936-37 and 1937-38 seasons there were decided decreases in abundance of beneficial insects while at the same time there were increases in mountain pine beetle broods.

Beneficial insects are most abundant in those trees which provide suitable host material at the time of oviposition.

Site moisture appears to influence the abundance of beneficials. Parasites and predators are most abundant on wet sites while robber work is greatest on dry sites.

Accessibility of host material influences the abundance of beneficials. Parasites which oviposit through the bark are limited by bark thickness, while those which go beneath the bark for oviposition are limited by the abundance of entrances such as mountain pine beetle parent-emergence holes.

Parasites are most abundant in small, thin-barked trees, while predators are most numerous in the larger, thick-barked trees.

Beneficial agents are not equally numerous throughout an infestation. Certain areas appear to contain many more beneficials than adjacent areas.

In general, the study appears to hold possibility for practical application along the lines which were set up in the objectives for the study.

Respectfully submitted,

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